Estimation of the Atmospheric CO_2 Concentration in Iraq

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Abstract

The yearly average of the atmospheric CO_2 concentration in (16) different stations over Iraq for thirty years (1961 – 1991) have been estimated by using sunshine duration, extraterrestrial radiation, global radiation, the clearness index, diffused solar radiation and gross CO_2 assimilation of plants. These parameters are used as an input data for some mathematical models. The monthly rate of a gross CO_2 assimilation of plants is calculated by using Light Use Efficiency Model (LUE) and solar radiation data of all locations for that period. The monthly average of other parameters is calculated by using solar radiation model.

The results of the yearly average of the atmospheric CO_2 concentration in Iraq is (362.4405 ppmv) that can be considered an acceptable one and closed to the global measured results (334.1171ppmv).

Keyword : Extraterrestrial radiation; Diffuse radiation; Global radiation; Gross CO_2 assimilation; Atmospheric CO_2 concentration; Greenhouse gases;

تخمين تركيز CO_2 الجوي في العراق

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الخلاصة

لقد جرى تخمين المعدل السنوي لتركيز ثاني اوكسيد الكاربون لستة عشر محطة مختلفة في انحاء العراق لثلاثين سنة (1961-1991) باستخدام فترة سطوع الشمس، الاشعاع الشمسي الخارجي، الاشعاع الكلي الواصل للارض، معامل الصفاء، الاشعاع الشمسي المتشتت و كمية ثاني اوكسيد الكاربون الكلية المستخلصة في النباتات. هذه المعلمات استخدمت كبيانات ادخال الى بعض النماذج الرياضية.ان المعدل الشهري لكمية ثاني اوكسيد الكاربون الكلية المستخلصة في النباتات حسبت باستخدام نموذج (LUE) لكل المواقع خلال تلك الفترة. اما المعدل الشهري لباقي المعلمات فقد حسبت باستخدام نموذج الاشعاع الشمسي.
ان النتائج المستحصلة للمعدل السنوي لتركيز ثاني اوكسيد الكاربون في عموم العراق هي 362.4405 ppmv وتعد مقبولة وقريبة للنتائج المحسوبة عالميا (334.1171ppmv)

1. Introduction

Climate changes caused by mankind activities and the potential effect of climate changes on ecosystem are drawing great attention in the scientific community and society. The main reason leading to climate changes is that air component concentrations have been changing and concentrations of carbon dioxide and ozone have been increased because of human activity enrichment. The CO_2 concentration in the atmosphere has risen from 290 ppmv to 380 ppmv since Industrial Revolution because of combustion of fossil fuel such as coal and oil and denudation of forest [1].

The concentration of carbon dioxide may reach 550 ppmv in the middle of 21st century according to today's human activity enrichment rate [2, 3].

This increased concentration of CO_2 has now, unequivocally, warmed the Earth. According to the Stefan-Boltzmann the blackbody temperature of earth is 249 ^{0}K. This can be compared to the actual average temperature of the Earth, 15 ^{0}C = 288K. Note that the Planck's temperature is much cooler! The difference, which amounts to nearly 40 ^{0}C, is due to the greenhouse effect caused by our atmosphere, the peak of the blackbody spectrum of the Earth is at 11.6 µm, which is in the thermal IR. CO_2 gas has a very strong absorption band at ~12 - 15µm, very close to the peak of the Earth's blackbody radiation, and then it is trapping outgoing IR radiation [4].

The growth rate in the concentration of CO_2 in the atmosphere has not been constant over the past half century. In 1958, at the beginning of the Mauna Loa (Hawaii) measurements, the growth rate was approximately (0.7 ppmv/yr). At the present time, it is about (1.9 ppmv/y) [4].

CO_2 concentrations are regularly measured from a number of sites throughout the world, including the South Pole, Barrow Alaska, American Samoa, Mauna Loa, etc. These sites are chosen to be far from human sources of CO_2 production, and thus the atmospheric CO_2 should be well mixed and the measurements represent global means.

In Iraq, the atmospheric CO_2 concentration was not measured practically or calculated theoretically. This paper will try to estimate the atmospheric CO_2 concentration in sixteen different locations in Iraq and compare these results with the source data of Mauna Loa (Hawaii)[5]. The selected locations were chosen for various weather conditions (e.g. south, middle and north) of Iraq.

One of the most important processes in plants is the photosynthesis which depends on two main parameters: atmospheric CO_2 concentration and light (solar radiation). A plant's photosynthetic rate can be determined from its assimilation rate of CO_2 [6].

There are many models that can be used to calculate CO_2 assimilation rate. One of them is light use efficiency model (LUE). It is often regarded as the measure of the plants ability to convert solar radiation into biomass[7]. In other word Light-use efficiency (LUE) is the ability of vegetated canopies to use light for photosynthesis. Together with remote sensing estimates of canopy cover and meteorological inputs, LUE provides a physical basis for scaling carbon uptake processes from the stand to the global scale. A better understanding of the factors that control LUE will result in improved global estimates of carbon uptake from the terrestrial biosphere [8].

2. Mathematical model

Solar radiation is one of the key environmental parameters driving photosynthesis, transpiration and net energy exchange at the earth's surface. Most models of carbon, water and energy fluxes in terrestrial ecosystem require solar radiation as an input [9].

The daily extraterrestrial radiation (R_o) for each day of year and for different latitudes can be estimated from the solar constant, the solar declination and time of year[10].

$$R_o = \frac{24*60}{\pi} G_{sc} d_r [w_s \sin(\varphi)\sin(\delta) + \cos(\varphi)\cos(\delta)\sin(w_s)] \quad .(1)$$

R_o: extraterrestrial radiation [MJ. m^{-2}. Day^{-1}]

G_{sc}: solar constant 0.082 [M J.m^{-2} –min^{-1}]

d_r: inverse related distance, Earth- Sun

W_s: Sun set hour angle [deg.]

φ : latitude [deg.]

δ : solar declination [deg.]

After the extraterrestrial radiation penetrates the atmosphere, some of this radiation is scattered, reflected or absorbed by the atmosphere components. The amount of radiation reach the earth's surface is known as global radiation or solar shortwave radiation (R_s). It can be calculated with Angstrom formula which relates solar radiation to extraterrestrial radiation and relative sunshine duration as follow[10];

$$R_s = \left[a_s + b_s \frac{n}{N} \right] R_o \quad ....(2)$$

R_s: solar shortwave radiation [MJ.m^{-2}.day^{-1}]

n: actual duration of sunshine [hour]

N: maximum possible duration of sunshine or daylight hour [hour]

n /N: relative sunshine duration.

$(a_s + b_s)$: fraction of R_o reaching the earth on clear day [N = n]

The value of a_s and b_s are variable parameters according to atmospheric conditions. We can use the value of a_s =0.25 and b_s=0.5 to approximate. They are recommended and applicable anywhere in the world [10].

The diffused solar radiation (R_d) that occurs when small particles, gas molecules, dust and clouds diffuse part of incoming solar radiation in random direction. It can be calculated by [11, 12].

$$R_d = R_s \,(1.39 - 4.027C + 5.53C^2 - 3.108C^3) \quad ... (3)$$

R_d: diffused solar radiation [MJ. m^{-2}. day^{-1}]

$C = R_s / R_o$: the clearness index.

Some fraction of solar radiation R_s (MJ. m^{-2}. day^{-1}) that incident at the top canopy is absorbed and the gross carbon uptake rate Pg (mole CO_2 m^{-2} day^{-1}) is proportional to the absorbed light[13]. The light use efficiency model is used to estimate the carbon uptake.

$$P_g \,\alpha\, f R_s$$

P_g: gross CO_2 assimilation (mole CO_2 m^{-2} day^{-1})

f: fraction of absorbed solar radiation

Adding the so-called LUE parameters (e) and (c) (mole/MJ) to convert from energy to quanta units we have,

$$P_g = e.f.c.\,R_s \quad .... (4)$$

The value of c typically varies over the range (2.1-2.7) mole/MJ and is typically close to 2.3 and the value of f is about 0.65[14]. e was not fundamental biochemical parameter of leaves, but was instead a canopy level parameter and that *e* would be very sensitive to the geometry of the incoming light. The sun leaves receiving high light will usually be saturated and any change in light has little impact on photosynthetic rates of those leaves. In contrast, leaves that are shaded receive lower light (mostly diffuse radiation) and these leaves are usually light-limited. Hence, any increase in light will increase the photosynthetic rates of the light limited leaves, and hence, the gross photosynthesis of the canopy. This has been formulated in sun shaded model [15]. Analysis of these models shows that e will be a function of geometric properties the incident light as well as the canopy geometric properties. e parameter was given as a function in terms of diffuse radiation and global radiation [16],

$$e \approx (0.024\, R_d / R_s) + 0.012 \quad \ldots\ldots\ldots\ldots (5)$$

The equation (4) will become,

$$P_g = (0.024\, R_d / R_s + 0.012)\, f.c.R_s \quad \ldots. (6)$$

The maximum leaf CO_2 assimilation rate under high light intensity is calculated as a function of the external (ambient air) CO_2 concentration [6].

$$P_{gmax} = (49.57/34.26) \times (1 - e^{(-0.208(CO_2 - 60)/49.57)}) \quad \ldots(7)$$

P_{gmax} : is the CO2 assimilation rate at light saturation is the initial light-use efficiency.

CO_2 : is the atmospheric CO_2 concentration in part per million volume unit (ppmv).

The atmospheric CO_2 concentration can be calculated from equation (7)

$$CO_2 = 60 - [(49.57/0.208).\ln(1 - (P_{gmax} / 49.57))] \quad ..(8)$$

The CO_2 assimilation-light response of individual leaves follows a saturation type of function, characterized by an initial slope (the initial light-use efficiency) and an asymptote, and is described by the negative exponential function [16].

$$P_g = P_{gmax}\,(1 - \exp(-f\, R_s / R_{ohm})) \quad \ldots\ldots... (9)$$

$$P_{gmax} = Pg / (1 - \exp(-f\, R_s / R_{ohm})) \quad \ldots.... (10)$$

$f\,R_s$ is the amount of absorbed radiation.

R_{ohm} is the solar radiation at half maximum gross assimilation of CO_2.

3. Result and Discussion

Iraq lies between latitudes 29̊ó. 5ó and 37̊ó.22ó north and between longitude 38̊ó 45ó and 48̊ó 45ó east. The stations selected in our present study are represented in table (5),which are:

1. Al-Basrah, Al-Nasriya, Al-Samawa, and Al-Amara (south of Iraq).
2. Baghdad, Haditha, Al-Rutba, Kerbala, Al-Hai, Al-Najaf and Al-Diwaniya(middle of Iraq).
3. Kirkuk, Khanaqin, Sulaymania, Al-Mosul and Zakho (north of Iraq).

The data source reported in this paper was supplied by relevant meteorological and solar radiation data were mainly taken from the Republic of Iraq Meteorological office (RIMO). The R_o , R_s, R_d, C, sunshine duration and atmospheric CO_2 measured values in a period (1961 – 1991) for all stations.

This result obtained by using the equations (1 to 10). R_o and R_s are evaluated by the equation 1 and 2 , table (1, 2) respectively. The value of a_s and b_s are a constant coefficients which is believed to be applicable at any where in world (a_s = 0.25, b_s=0.5) [10]. The clearness index $C(R_s/R_{so})$ represents the percentage deflecting by the sky of the incoming global solar radiation and therefore indicated the level of availability solar radiation and changes in atmospheric condition in a given locality, while relative sunshine (n/N) is a measure of cloud cover. To calculate the diffused solar radiation (R_d), the equation (3) was used as presented in table (4).

The maximum values of $R_{o,}$ R_s and R_d for all locations are observed in April, May, June, July, and August, while the minimum values appeared in January, February, November and December. These results can be illustrated because of the sunshine duration of day (*n/N*) and clearness index (C) in June and July were maxima. Also, these changing in results due to turbidity factor and seasonal variation which dependent on the position of the sun.

The yearly average of the atmospheric CO_2 concentration for all locations was estimated by equation (10) as in table (5). In general, the yearly average of the atmospheric CO_2 concentration in Iraq was (362.4405 parts per million volume (ppmv)) that can be considered an acceptable one and closed to the global measured results (334.1171ppmv) according to Mauna Loa (Hawaii) measurements [5]. This site are chosen to be far from human sources of CO_2 production, and thus the atmospheric CO_2 should be well mixed and the measurements represent global means. Thus, the increasing of the atmospheric CO_2 concentration in Iraq was happened because of the human enrichment. All these calculations have been made by using Matlab program [appendix A].

4. Conclusion

Our study shows, it is possible to obtain the extraterrestrial radiation, global solar radiation, diffuse solar radiation by mathematical model that has been depended on local atmospheric condition and geographical parameter (i.e. latitude). This model can be used in any location at Iraq and other sites. The atmospheric CO_2 concentration can be estimated theoretically is depending on solar radiation parameters and gross CO_2 assimilation rate of plants. This model has been developed taking into account the experimental data from the meteorological data, theoretically calculated upon the atmosphere conditions, and the ground reflection (albedo) effects.

This model provides a good estimation for R_o, R_s, R_d, and atmospheric CO_2 concentration and can be said the model performs well. The estimation provided by the model can be used for estimation the yearly of atmospheric CO_2 concentration in Iraq to observe the yearly increasing of it. The yearly average of the atmospheric CO_2 concentration in Iraq was (362.4405 ppmv) within the period from (1961-1991) that can be considered an acceptable one and closed to the global measured results

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6. Appendix

Appendix(A): The atmospheric CO2 concentration Matlab program

```
clc
format short
f=0.65;                        % f fraction of absorbed radiation at canopy
as=0.25;bs=0.5;                % as and bs are constant values
c=2.3;                         % c Light Use Efficiency parameter
%ro is the extraterrestrial solar radiation (MJ/m^2*day)
ro=input('extraterrestrial solar radiation')
nN=input('relative sunshine duration')
rs=(as+bs*nN).*ro;      % rs is a global solar radiation (MJ/m^2*day)
Rs=30*rs;               % Rs is a global solar radiation (MJ/m^2*month)
Ro=30*ro;        % Ro is the extraterrestrial solar radiation (MJ/m^2*month)
C=Rs./Ro;               % C:the clearness index.
% Rd is a diffuse solar radiation (MJ/m^2*month)
Rd=Rs.*(1.39-4.027*C+5.53*C.^2-3.108*C.^3);
e=0.024*(Rd./Rs)+0.012;                %e represent lue parameter
Pg=e*f*c.*Rs;                          % Pg is the gross Co2 assimilation
rate
Rh=max(Ro)*0.5;
for x=1:12
A(:,x)=(f*(Rs(:,x))/Rh(1,x));
end
%Pgmax is a maximum Co2 assimilation rate at high light
Pgmax=Pg./(1-exp(-A));
Pgmax=sum(Pgmax)/12;
Co2=60-(49.57/0.208)*log(1-(Pgmax/49.57))% Co2:the atmospheric CO2
concentration
co2=sum(Co2)/16
```

Table (1): The monthly average of extraterrestrial solar radiation (R_o) for all selected locations (MJ. m^{-2}. $month^{-1}$

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Al-Basrah	629.4	771	941.4	1098	1199.1	1204.2	1244.7	1134.9	1001.4	819.3	661.8	588.9
Al- Nasiriya	619.8	775.5	935.7	1095.6	1198.2	1225.8	1213.8	1132.8	991.8	812.4	651.9	606.6
Al-Samaua	616.5	758.7	933	1094.7	1198.2	1236.6	1213.8	1095	1019.7	808.8	647.7	575.7
Al-Amara	604.8	750.9	926.4	1091.4	1199.1	1236.6	1215.6	1117.2	984.3	801	639	564
Al-Diwaniya	603	748.8	929.7	1091.1	1189.2	1236.6	1215.3	1129.8	984.3	801	638.7	563.7
Al-Najaf	603	748.8	929.7	1091.1	1189.2	1236.6	1215.3	1129.8	984.3	801	638.7	563.7
Al-Hai	601.5	745.8	922.8	1089.6	1198.5	1238.1	1215.6	1119.6	981.6	796.5	633.3	557.7
Kerbala	592.8	738.6	917.7	1086.9	1197.9	1236.6	1215.3	1126.8	977.4	790.2	624.9	551.1
Al-Rutbah	583.5	730.8	912.3	1089.3	1197	1240.5	1216.2	1128	978.3	789.9	624.9	549.9
Baghdad	580.2	726.3	909	1082.1	1198.2	1241.4	1216.8	1125	970.5	779.1	612.9	538.2
Haditha	626.7	713.7	899.1	1077.6	1198.2	1243.5	1217.7	1122.6	962.1	767.4	598.8	525.3
Khanoqin	566.1	709.2	895.8	1075.8	1198.2	1246.5	1216.8	1121.4	960	763.2	593.7	517.2
Kirkuk	540.6	692.4	885.9	1068.3	1196.7	1244.7	1221	1117.2	948.6	746.7	574.8	497.1
Al-Sulaimaniya	529.8	690.6	884.7	1067.7	1196.1	1244.4	1219.5	1116.6	947.1	744.3	571.8	493.8
Al-Mosul	525.3	700.8	871.8	1063.2	1196.4	1245.9	1217.7	1112.4	939.9	734.4	560.1	481.2
Zakho	507	661.5	858.9	1055.7	1194.6	1253.1	1218.3	1108.2	929.1	718.5	542.4	462.3

Table (2): The monthly average of Global solar radiation (R_s) for all selected locations (MJ. m^{-2}. $month^{-1}$)

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Al-Basrah	371.35	466.46	555.43	651.11	743.44	788.75	809.06	714.99	680.95	540.74	410.32	353.34
Al- Nasiriya	350.19	453.67	533.35	624.49	694.96	710.96	722.21	702.34	644.67	511.81	368.32	363.96
Al-Samaua	360.65	447.63	550.47	645.87	718.92	822.34	837.52	766.50	703.59	513.59	388.62	328.15
Al-Amara	335.66	439.28	518.78	627.56	707.47	822.34	814.45	770.87	629.95	548.69	380.21	324.30
Al-Diwaniya	340.70	438.05	539.23	627.38	701.63	816.16	814.25	768.26	659.48	504.63	357.67	318.49
Al-Najaf	346.73	449.28	539.23	627.38	707.57	816.16	820.33	762.62	659.48	504.63	383.22	321.31
Al-Hai	348.87	440.02	544.45	637.42	731.09	835.72	826.61	772.52	662.58	509.76	395.81	323.47
Kerbala	340.86	446.85	541.44	608.66	682.80	828.52	826.40	771.86	664.63	505.73	378.06	311.37
Al-Rutbah	335.51	438.48	542.82	637.24	742.14	849.74	845.26	789.60	665.24	505.54	387.44	313.44
Baghdad	330.71	428.52	536.31	649.26	736.89	850.36	833.51	781.88	664.79	498.62	367.74	309.47
Haditha	344.69	417.51	530.47	630.40	742.88	826.93	828.04	763.37	644.61	491.14	356.29	288.92
Khanoqin	302.86	379.42	488.21	607.83	706.94	810.23	803.09	740.12	624.00	461.74	347.31	268.94
Kirkuk	273.00	366.97	469.53	592.91	718.02	790.38	787.55	748.52	635.56	462.95	324.76	248.55
Al-Sulaimaniya	278.15	348.75	437.93	587.24	729.62	846.19	835.36	770.45	648.76	457.74	317.35	276.53
Al-Mosul	233.76	367.92	470.77	590.08	819.53	847.21	834.12	767.56	648.53	459.00	316.46	243.01
Zakho	240.83	327.44	425.16	559.52	698.84	814.52	822.35	742.49	622.50	431.10	284.76	226.53

Table (3): The monthly average of clearness index (C) for all selected locations

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Al-Basrah	0.590	0.605	0.590	0.593	0.620	0.655	0.650	0.630	0.680	0.660	0.620	0.600
Al- Nasiriya	0.565	0.585	0.570	0.570	0.580	0.580	0.595	0.620	0.650	0.630	0.565	0.600
Al-Samaua	0.585	0.590	0.590	0.590	0.600	0.665	0.690	0.700	0.690	0.635	0.600	0.570
Al-Amara	0.555	0.585	0.560	0.575	0.590	0.665	0.670	0.690	0.640	0.685	0.595	0.575
Al-Diwaniya	0.565	0.585	0.580	0.575	0.590	0.660	0.670	0.680	0.670	0.630	0.560	0.565
Al-Najaf	0.575	0.600	0.580	0.575	0.595	0.660	0.675	0.675	0.670	0.630	0.600	0.570
Al-Hai	0.580	0.590	0.590	0.585	0.610	0.675	0.680	0.690	0.675	0.640	0.625	0.580
Kerbala	0.575	0.605	0.590	0.560	0.570	0.670	0.680	0.685	0.680	0.640	0.605	0.565
Al-Rutbah	0.575	0.600	0.595	0.585	0.620	0.685	0.695	0.700	0.680	0.640	0.620	0.570
Baghdad	0.570	0.590	0.590	0.600	0.615	0.685	0.685	0.695	0.685	0.640	0.600	0.575
Haditha	0.550	0.585	0.590	0.585	0.620	0.665	0.680	0.680	0.670	0.640	0.595	0.550
Khanoqin	0.535	0.535	0.545	0.565	0.590	0.650	0.660	0.660	0.650	0.605	0.585	0.520
Kirkuk	0.505	0.530	0.530	0.555	0.600	0.635	0.645	0.670	0.670	0.620	0.565	0.500
Al-Sulaimaniya	0.525	0.505	0.495	0.550	0.610	0.680	0.685	0.690	0.685	0.615	0.555	0.560
Al-Mosul	0.445	0.525	0.540	0.555	0.685	0.680	0.685	0.690	0.690	0.625	0.565	0.505
Zakho	0.475	0.495	0.495	0.530	0.585	0.650	0.675	0.670	0.670	0.600	0.525	0.490

Table (4): The monthly average of diffused solar radiation (R_d) for all selected locations (MJ. m^{-2}. $month^{-1}$)

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Al-Basrah	111.68	135.05	167.04	194.36	206.88	198.32	206.58	193.55	157.61	133.84	114.18	103.62
Al- Nasiriya	111.88	138.13	168.39	197.17	214.20	219.14	214.50	195.44	164.61	138.55	117.68	106.74
Al-Samaua	109.81	134.62	165.55	194.24	210.84	200.28	186.93	164.61	157.04	137.07	113.97	103.61
Al-Amara	109.79	133.75	167.71	195.78	212.77	200.28	195.11	172.06	165.72	124.74	112.92	101.17
Al-Diwaniya	108.85	133.38	166.20	195.73	211.01	202.01	195.06	177.82	157.98	136.60	115.63	101.76
Al-Najaf	108.17	131.76	166.20	195.73	210.16	202.01	193.21	179.62	157.98	136.60	112.39	101.45
Al-Hai	107.53	132.33	163.74	194.08	208.93	196.83	191.32	172.43	156.05	134.10	108.65	99.70
Kerbala	106.34	129.38	162.84	196.76	215.58	198.48	191.28	175.48	153.83	133.04	109.46	99.48
Al-Rutbah	104.67	128.59	161.22	194.03	206.51	193.19	185.11	169.57	153.98	132.99	107.81	98.96
Baghdad	104.42	128.87	161.29	190.41	207.83	193.33	189.50	171.23	151.14	131.17	107.85	96.54
Haditha	114.05	127.13	159.54	191.94	206.72	201.40	191.66	176.69	154.42	129.20	105.82	95.60
Khanoqin	103.72	129.93	163.41	194.20	212.61	206.88	198.77	183.19	159.33	133.69	105.75	95.28
Kirkuk	100.02	127.10	162.62	193.92	210.58	210.95	204.14	179.31	152.25	128.83	103.76	92.09
Al-Sulaimaniya	97.43	127.78	164.07	194.31	208.52	195.86	189.92	171.96	147.50	129.10	103.79	89.39
Al-Mosul	97.99	128.88	159.39	193.00	186.32	196.09	189.64	171.32	144.75	125.99	101.11	89.03
Zakho	94.35	122.68	159.29	193.79	212.78	207.98	193.69	177.87	149.12	126.43	99.75	85.82

Table (5): The annual average of the Atmospheric CO_2 concentration (ppmv) for each station .In column one the name of the stations, in columns 2-3 the altitude and Elevation

	Location	Latitudes(N)	Elevation(m)	Atmospheric CO_2 concentration (ppmv)
1	Al-Basrah	30° 31′	2.4	363.0456
2	Al- Nasiriya	31° 01′	3	365.5226
3	Al-Samaua	31° 16′	6	358.3507
4	Al-Amara	31° 50′	7.5	360.5671
5	Al-Diwaniya	31° 57′	20.4	362.4433
6	Al-Najaf	31° 57′	50	360.3263
7	Al-Hai	32° 08′	14.9	357.2419
8	Kerbala	32° 34′	29.0	358.4071
9	Al-Rutbah	33° 02′	615.5	355.9906
10	Baghdad	33° 18′	34.1	356.5383
11	Haditha	34° 08′	108	360.4116
12	Khanoqin	34° 21′	202.2	369.0323
13	Kirkuk	35° 28′	330.8	368.8321
14	Al-Sulaimaniya	35° 32′	853.0	364.2604
15	Al-Mosul	36° 19′	222.9	363.9141
16	Zakho	37° 08′	442.	374.1648